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How does education at all levels influence productivity growth? Evidence from the Chinese provinces

Ping HUA*

CERDI-IDREC, CNRS-Université d'Auvergne
65, boulevard François Mitterrand,
63000 Clermont-Ferrand, France.
Tel: 00 33 1 39 14 81 25
Fax: 00 33 4 73 43 12 28

Email: P.Hua@u-clermont1.fr.

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Summary:

This article investigates the different effects that primary education, secondary education and university education exert on total factor productivity growth and its two components. Firstly, we give the theoretical arguments explaining these effects. Then, for the twenty-nine Chinese provinces we calculate DEA Malmquist indices of productivity growth for the period from 1993 to 2001. Finally we present a panel econometric model of productivity growth. We show that university education has a favourable effect both on efficiency growth and technical progress, while primary education and secondary education have an unfavourable one on efficiency growth. Moreover, the favorable effect of university education on efficiency change is through the reallocation of university-educated workers into the more efficient non-state sector.

1. Introduction

The Chinese economy has increased at an annual average growth rate of 9.8% in real terms from 1978 to 2002[1]. There is an on-going debate on whether this growth rate is mainly driven by productivity or factor accumulation (Chow, 1993; Young, 2000). Several recent studies (Guillaumont Jeanneney and Hua, 2003; Zheng and Hu, 2004) showed an alarming decreasing productivity growth in 1990s[2]. Facing this debate and to be conscious of the importance of education in improving productivity to keep long term growth, the Chinese government has given its priority on education since the beginning of 1990s, in particular on higher education[3]. The number of new students admitted to the regular institution of university education has passed from 0.62 millions in 1991 to 3.4 millions in 2002, with an annual average growth rate of 15.2%. Did this education policy really favor to the productivity improvement in China? If yes, how?

Theoretically, education allows workers to use existing physical capital more efficiently, to drive the development and diffusion of new technologies and to improve the capacity of imitation and adoption of the techniques previously developed by more advanced countries. Education has also positive external effects on productivity (Sarquis and Arbache, 2002). Consequently, it plays a positive role in efficiency improvement and technical change, so productivity growth.

Despite this positive role of education in theoretical growth models, most empirical papers within this field have found at best mixed evidence supporting this hypothesis (Pritchett, 2001; Temple, 2001). This may firstly be due to the problems of education measures (Barro, 1991, Krueger and Lindahl, 2001). In fact, most papers are based on cross-countries studies and they have not concurred on education measure. Educational attainment, enrolment rates or educational spending and related inputs are often used as measures of a country's human capital[4]. However, they are not really pertinent to measure education stock. It may also be due to influential outliers (Temple, 1999). It may finally be due to the fact that different education levels may exert different (positive or negative) effects on technical progress and efficiency, and these positive or negative effects may offset each other to lead an

[1] According to *Chinese Statistical yearbook*, 2003.

[2] Guillaumont Jeanneney and Hua (2003) estimated that the efficiency change decreased 0.3% per year on average for the period from 1993 to 2001 and 0.31% for the period from 1995 to 2001 (Zheng and Hu, 2004).

[3] Education in China is classified as kindergarten (ages 3-6), primary education (ages 6-12), secondary education (ages 12-18), including junior and senior secondary schools, specialized secondary schools, vocational schools and technical training schools, higher education, including universities and colleges and postgraduate programs (4-5 years for a B.A. degree, 7-8 years for a Master degree and 10-11 year for a PhD).

[4] Barro (1991) and Barro and Lee (1993, 2000) made extensive effort to improve the measures of human capital.

insignificant total effect of education on productivity (our explanation)[5]. However, many papers in the field studied the effect of education on productivity, regardless of the education level (Temple, 2001). They neither distinguish education levels nor split productivity into efficiency and technical progress. A few papers which studied the effects of different education levels to the growth mechanism give different conclusions. Barro and Lee (1997) conclude that primary and tertiary education have negative and insignificant impacts on growth. Sachs and Warner (1995) find a positive, but still insignificant impact of both primary and secondary education on growth. Self and Grabowshi (2004) show that primary education is the main causal force in economic growth in the case of India.

In order to test our arguments, we use in this paper the proportion of educated workers relative to total population as measures of education stock;[6] and split it into three levels, i.e. primary-education, secondary-education or university-education. More precisely, they are respectively defined as the ratios of the total number of graduates only from primary schools, only from secondary schools and from universities relative to total population[7]. We examine the different impacts of these three variables of education levels on efficiency improvement and technical progress, and this after the examination of potential outliers.

If the primary educated people in China decreased slightly from 35% in 1990 to 31% in 2002, it increased quickly from 32% to 47% for the secondary educated people and from 2% to 5% during the same period for university educated people (figure 1). Moreover, these three education levels differ significantly from one province to another one[8]. For example, in Guangxi province, only 1% of the population has received university education on average during the period from 1990 to 2002, while in Beijing there is 13% of population having receiving university education. On the contrary, there are respectively 44% and 19% of the population having attainted only primary education respectively for Guangxi and Beijing (see table 1).

[5] Our econometric results confirm this explanation.
[6] The detail of education stock calculation is given in 5.1 section.
[7] Total population is equal to the sum of without educated, primary-educated, secondary-educated and university-educated population.
[8] China is composed of 22 provinces (Hebei, Liaoning, Jiangsu, Zhejiang, Fujian, Shangdong, Guangdong, Hainan, Shanxi, Jilin, Heilongjiang, Henan, Anhui, Hubei, Hunan, Jiangxi, Gansu, Shaanxi, Sichuan, Guizhou, Yunnan and Qinghai), four autonomous municipalities under the direct control of central government (Beijing, Tianjin, Shanghai et Chongqing), and five autonomous regions (Guangxi, Inner Mongolia, Ningxia, Xinjiang and Tibet). In our econometric analysis, the autonomous region of Tibet is not included for lack of data, the statistics of Chongqing, created in 1997, have been included in those of Sichuan, this leads to retain 29 provinces.

Figure 1. Evolution of the different education levels in China

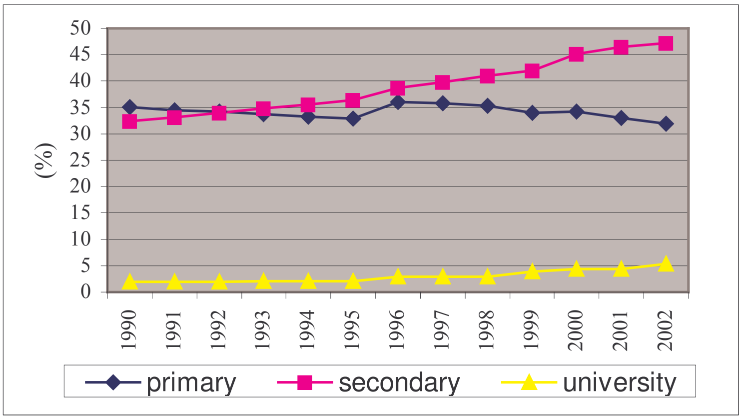


Table 1. Education variables in the Chinese provinces (%)

	Primary education			Secondary education			University		
	1990	2002	Average	1990	2002	Average	1990	2002	Average
Beijing	22,58	14,40	**18,54**	49,53	57,80	**54,89**	9,30	19,86	**13,39**
Tianjin	29,64	22,23	**28,19**	45,29	57,52	**51,68**	4,67	10,14	**6,19**
Hebei	36,81	32,54	**35,15**	32,12	51,17	**40,37**	0,96	4,43	**1,72**
Shanxi	35,71	29,54	**32,07**	38,06	54,24	**44,81**	1,38	4,32	**2,45**
Inner Mongolia	33,40	28,12	**31,24**	35,53	49,93	**42,15**	1,48	5,34	**2,61**
Liaoning	34,27	28,49	**32,39**	43,25	57,23	**50,01**	2,60	5,28	**3,91**
Jilin	35,33	30,91	**34,41**	39,01	54,62	**47,22**	2,15	6,23	**3,39**
Heilongjiang	34,09	29,71	**31,82**	40,19	55,41	**47,43**	2,14	4,65	**3,18**
Shanghai	22,68	16,98	**22,18**	51,12	58,00	**58,17**	6,53	14,62	**9,45**
Jiangsu	34,79	30,53	**33,16**	35,10	49,52	**42,00**	1,47	3,66	**2,53**
Zhejiang	39,66	32,48	**36,15**	30,75	45,34	**38,17**	1,17	5,48	**2,00**
Anhui	34,69	34,48	**35,96**	25,00	43,32	**32,56**	0,88	2,49	**1,35**
Fujian	43,24	36,64	**41,94**	23,85	42,77	**32,30**	1,23	3,97	**1,86**
Jiangxi	40,67	38,55	**40,63**	25,94	42,84	**33,74**	0,99	2,69	**1,47**
Shandong	36,26	26,35	**33,23**	32,32	52,75	**40,47**	0,98	5,33	**1,82**
Henan	34,73	27,54	**33,57**	33,61	54,55	**41,23**	0,85	4,01	**1,61**
Hubei	35,83	37,47	**36,24**	32,03	42,46	**38,43**	1,57	4,60	**2,45**
Hunan	42,07	35,13	**40,14**	30,58	48,23	**38,08**	1,14	4,10	**1,91**
Guangdong	40,45	34,34	**37,88**	31,97	48,13	**38,20**	1,34	4,80	**2,07**
Guangxi	45,04	36,90	**43,65**	25,95	45,09	**33,38**	0,79	3,24	**1,21**
Sichuan	43,85	37,64	**41,98**	27,05	41,64	**32,83**	0,96	3,44	**1,66**
Guizhou	37,34	38,85	**39,00**	18,57	34,17	**23,86**	0,78	3,20	**1,43**
Yunnan	37,91	41,85	**40,20**	17,89	28,62	**22,95**	0,81	1,81	**1,25**
Shaanxi	31,13	33,56	**32,06**	33,61	45,06	**38,56**	1,67	3,75	**2,75**
Gansu	29,13	35,93	**30,96**	24,68	37,92	**30,14**	1,10	2,86	**1,78**
Qinghai	26,49	34,76	**27,46**	26,04	33,46	**28,61**	1,49	2,88	**2,14**
Ningxia	29,38	30,81	**29,68**	28,27	41,49	**34,99**	1,61	5,16	**2,62**
Xinjiang	36,42	35,19	**35,88**	31,03	45,79	**36,74**	1,85	9,71	**3,90**
Hainan	34,58	31,95	**34,63**	32,87	49,91	**36,41**	1,24	3,32	**1,96**

Sources: China Statistical Yearbook.

The objective of this paper is to measure the impacts of these three different education levels on efficiency improvement, technical progress, and thus productivity growth. The rest of this paper is organized as follows. In section 2, we present theoretical arguments explaining the different effects of education levels on productivity. We calculate then productivity growth and its two components thanks to DEA Malmquist indices (DEA Envelopment Analysis) in section 3. We present an econometric model in section 4. This model is applied to the panel data of the twenty-nine Chinese provinces over the period 1993-2001, using Generalized Moments Model. We estimate successively efficiency variation, technical progress and total factor productivity growth as a function of these three variables of education levels, of public employment representing the main channel through which university-educated workers are reallocated out, and some other control variables. The results corroborate our assumption that university education exerts a positive effect both on efficiency growth and technological change, while primary education and secondary education have a negative one on efficiency growth. Moreover, the favorable effect of university education on the efficiency change is through the reallocation of the university-educated workers into the more efficient non-state sector.

2. Theoretical frameworks for education and productivity

The basic hypothesis we claim in this study is that different education levels may exercise different (positive or negative) effects on technological progress, on technical efficiency improvement, thus on productivity. This may explain why the positive role of human capital in theoretical models is not always confirmed by empirical results[9].

2.1. Why different education levels may have different effects on productivity?

Several theoretical arguments explain the role of education in improving productivity growth. Education, which produces human capital, is a crucial determinant of productivity growth. The theory of human capital, born in the early 1960s, indicates that human capital constitutes one of the main explanatory factors of economic growth by improving the quality of labor force and thus increasing its productive capacity. Therefore, education is considered as an additional productive factor in neo-classical growth models in which technological

[9] The problems of education measures may also explain the paradox results as well as outliers.

progress is exogenous (Mankiw, 1995). But the role of education in production is beyond that of physical capital (Nelson and Phelps, 1966). In fact, education exercises an impact on the speed of technological catch-up and diffusion. It facilitates the ability of a nation to adopt, assimilate and implement new technologies from other countries and determines the ability of a nation to innovate domestically (Romer, 1990). If the lack of physical capital could restrain technical development, the lack of well-educated people could mean that the country has non-ability to use or create new technologies. Education is a prerequisite for economic and total factor productivity growth through its contribution to both adoption and innovation (Benhabib and Spiegel, 1994). Furthermore, it is one of the driving forces in sustained growth in the endogenous growth theory due to spillover effects that negate diminishing returns in production (Lucas, 1988; Romer, 1986, 1990). Finally, education is a necessary complement to investment in physical capital; and relatively low stocks of complementary human capital explain why physical capital does not flow from rich to poor countries (Lucas, 1990).

If education should play a positive effect in improving technological progress, we claim here that the ability of a nation to adopt, assimilate and implement new technologies from other countries should depend on education levels. If university-educated people exert a positive effect on technical progress through research and development, secondary-educated and primary-educated people may not exert this positive effect. Romer (1990) indicated that the existence of a sector of research and development in an economy is the mechanism through which sustained growth is reached. The most highly qualified people are, the greater the production is. University-educated workers facilitate the innovation of new ideas, new technologies and new products. They contribute moreover significantly to the imitation, the adoption and the use of technologies previously developed by more advanced countries. This is why the Chinese government provides quite advantage measures to attract the oversea Chinese university-educated people to create their technological enterprises in China. Finally, university education plays positive external effects through endogenous technical progress and competitive diffusion to improve know how through innovation and imitation (Sarquis and Arbache, 2002), and thus generates the growth from the existence of non-diminishing returns on the accumulable factors. These external effects are particularly important for the countries as China where the economy is still at a lower stage of development, but in a more and more competitive environment. Consequently, we wait for a positive effect of university education on technological change, but this effect may not be significant for secondary education and primary education.

Once the technologies are installed in place, education is a fundamental element in determining the efficiency in the use, the adoption and the imitation of new technologies. Once again, if education should exert a positive effect on efficiency improvement, the absorptive capacity of agents should depend on education levels. The presence of university-educated people is favorable to a good management and thus to an improvement of technical efficiency, and this may be less evident for primary and secondary educated people. Thus, we suppose here that university educated people should improve more easily efficiency relative to secondary-educated and primary-educated people.

Finally, we claim here that this efficiency improvement depends on the sector in which people work. As the state-owned sector in China is not efficient because of its soft budgetary constraints, people need not or are not incited to work efficiently, even if they may do not exert a negative effect. Moreover, as the wages for the university-educated people in the state-owned enterprises are lower than those in the non-state owned sector, these people are incited to move out the sector (Zheng and Hu, 2004). On the contrary, for the less-educated people, the wages in the state-owned sector are higher than those in the non-state owned sector; they prefer to stay in the sector. This reallocation of university-educated labor moving out the state-owned sector should improve the efficiency. But the abundance of primary-educated and secondary-educated people in the state-owned sector may exert a negative or insignificant effect on efficiency improvement. Consequently, we expect that the positive effect of the university-educated people on efficiency improvement is through their reallocation into the non state-owned sector, but this effect is not certain for secondary and primary education.

In sum, education can influence productivity growth by stimulating technological progress and increasing the efficiency. The ample of this influence varies furthermore with education levels and depends on the sector in which people work.

2.2. Theoretical model for the productivity effects of different education levels

We write the aggregate production function to study the effects of three education levels on growth as fellows: $Y = TFPK^{\alpha} H_p^{\beta_p} H_s^{\beta_s} H_u^{\beta_u} L^{1-\alpha-\beta}$

Where Y is output, TFP total factor productivity, K physical capital, H_p, H_s and H_u respectively aggregate stocks of primary education, secondary education and university and L labor force. We have $\beta=\beta_p+\beta_s+\beta_u$ and $\alpha+\beta=1$

We suppose that H_p, H_s and H_u represent respectively the total years of primary education, secondary education and university as in Temple (2001), and E_p, E_s and E_u their corresponding average years. We have $E_p=\frac{H_p}{L}$, $E_s=\frac{H_s}{L}$, $E_u=\frac{H_u}{L}$. Therefore, we have $E=E_p+E_s+E_u=\frac{H_p+H_s+H_u}{L}$

Thus, we rewrite the production function as $Y=TFPK^{\alpha}E_p^{\beta_p}E_s^{\beta_s}E_u^{\beta_u}L^{1-\alpha}$

Output is therefore a function of capital, labor and three indices of labor quality.

Then, in order to make the productivity effect to vary with education levels, we suppose that E_p, E_s and E_u have flexible specification as in Hall and Jones (1999) among others as: $E_p=e^{\phi(E_p)}$, $E_s=e^{\phi(E_s)}$ and $E_u=e^{\phi(E_u)}$. The functions $\phi(E_p)$, $\phi(E_s)$ and $\phi(E_u)$ show how the productivity effect varies with primary education, secondary education and university education, and this relative to one with no education, i.e. E=0 and $\phi(0)=0$.

We obtain $Y=TFPK^{\alpha}e^{\beta_p\phi(E_p)}e^{\beta_s\phi(E_s)}e^{\beta_u\phi(E_u)}L^{1-\alpha}$.

Finally, the above production function can be written into growth rate such as:

$$\dot{Y}=T\dot{F}P+\alpha\dot{K}+\beta_p\phi(E_p)+\beta_s\phi(E_s)+\beta_u\phi(E_u)+(1-\alpha)\dot{L}$$

As productivity growth is the sum of technical progress ($\dot{TP}$) and efficiency change ($\dot{TE}$), we rewrite the above equation as:

$$\dot{Y}=\dot{TP}+\dot{TE}+\alpha\dot{K}+\beta_p\phi(E_p)+\beta_s\phi(E_s)+\beta_u\phi(E_u)+(1-\alpha)\dot{L}$$

3. Measurement of total factor productivity and its two components

Several methods can be used to calculate productivity. We can use partial productivity, calculated simply as production divided by one production factor, but this measurement is biased because of possible substitution between production factors. In order to avoid this bias, we can calculate total factor productivity (TFP), measured as ratio between production (added value) and weighting sum of production factors. The traditional method consists to estimate one Cobb-Douglas production function and to consider the part of product non explained by production factors or the residual of the function as TFP measurement. But the residual represents really technological level only with parfait technical efficiency hypothesis. This last hypothesis is contestable in particular for transition countries as China. Malmquist index allows to ignore this hypothesis and to decompose total factor productivity into technical efficiency and technical progress. Consequently, we use in this paper Malmquist index to calculate productivity growth.

3.1. DEA Malmquist index

Malmquist index is a total factor productivity index, calculated relative to previous year. It is a geometric average of efficiency index and technical progress index. Efficiency index is the ratio between observed production to potential one, taken account of available technologies. Technical progress index is potential production, which may be measured on the base of the production factors in current or in previous year. Malmquist index of technical progress is then calculated as geometric average of the two indices.

Malmquist index calculation uses distance functions. It consists to calculate the ratio of realized production to frontier production, by combining successively the levels of production factors and available technologies. This leads to measure four distance functions. Two first functions are calculated by considering the technologies of period t and successively the amounts of production factors in t and t+1, i.e. $d_o^t(Y_t,X_t)$ and $d_o^t(Y_{t+1},X_{t+1})$. We obtain the first index of productivity such as:

$$M_o^t(Y_{t+1,}Xt+1,Y_t,X_t)=\left[\frac{d_o^t(Y_{t+1},X_{t+1})}{d_o^t(Y_{t,}X_t)}\right].$$

According to the same principle, two other functions are calculated by considering the technologies of period t+1 with the amounts of production factors in t, then in t+1, such as: $d_o^{t+1}(Y_t,X_t)$ and $d_o^{t+1}(Y_{t+1},X_{t+1})$. We obtain as before productivity index such as:

$$M_o^{t+1}(Y_{t+1,}Xt+1,Y_t,X_t)=\left[\frac{d_o^{t+1}(Y_{t+1},X_{t+1})}{d_0^{t+1}(Y_t,X_t)}\right]$$

In order to avoid choosing an arbitrary benchmark or technology reference, we follow Färe et al (1994) to calculate Malmquist index of total factor productivity as a geometric mean of the two preceding indices, such as:

$$M_o^{t+1,t}(Y_{t+1},X_{t+1,}Y_t,X_t)=\left[\frac{d_o^t(Y_{t+1},X_{t+1})}{d_o^t(Y_{t,}X_t)}*\frac{d_o^{t+1}(Y_{t+1},X_{t+1})}{d_0^{t+1}(Y_t,X_t)}\right]^{1/2}$$

The precedent equation may be written as following:

$$M_o^{t+1,t}(Y_{t+1},X_{t+1,}Y_t,X_t)=\frac{d_o^{t+1}(Y_{t+1,}X_{t+1})}{d_0^t(Y_,X_t)}\left[\frac{d_o^t(Y_{t+1,}X_{t+1})}{d_o^{t+1}(Y_{t+1},X_{t+1})}\frac{d_o^t(Y_{t,}X_t)}{d_o^{t+1}(Y_t,X_t)}\right]^{1/2}$$

The first term represents technical efficiency change between two periods, i.e. convergence of the provinces towards frontier production. The second represents technical progress or production frontier movement. Malmquist index may be inferior, equal or superior to one, corresponding respectively to deterioration, stagnation or improvement of total factors productivity.

The calculation of Malmquist index implicates to measure production frontier or efficiency frontier. To calculate this frontier, the most used non-parametric method is DEA method (Data Envelopment Analysis). It consists to use linear programming methods to construct a non-parametric piecewise surface (or frontier) over the data, so that to be able to calculate efficiencies relative to this surface, with hypotheses relative to convex and monotony of all production possibilities. Consequently, with DEA method, we can build an empirical production frontier by piecewise surfaces that are constituted by the most efficient provinces and measure the distance of each province to this frontier as efficiency (Battest et al., 1997). In other words production frontier or the best practice (Fare et al, 1994) is common for all provinces. The last ones have different indices of technical progress because they do not use the same production factors and thus do not have same innovation level.

The advantage of the DEA non-parameter method is that it does not impose the same production function on all the Chinese provinces, as should be parametric method. This is why we choose to use it. Its inconvenient is however not to take into account measurement errors and random shocks as in return parametric method allows [10].

3.2. Data and results

Malmquist index of total factor productivity and its two components, technical progress and efficiency, are calculated from 1993 to 2001 for twenty-nine Chinese provinces[11]. DEAP software version 2.1 is applied (Coelli, 1998).

The data on GDP and employment are issued from the annual editions of *China Statistical Yearbook*. Real GDP is nominal GDP divided by its deflator. The capital stock for each province is calculated from gross fixed capital formation (GFCF), which is obtained

[10] The growth rate of GDP non explained by the change of production factors can be related to some phenomena which have any relationship with TFP, such as measurement errors, climate changes, etc.

[11] China is composed of 22 provinces (Hebei, Liaoning, Jiangsu, Zhejiang, Fujian, Shangdong, Guangdong, Hainan, Shanxi, Jilin, Heilongjiang, Henan, Anhui, Hubei, Hunan, Jiangxi, Gansu, Shaanxi, Sichuan, Guizhou, Yunnan and Qinghai), four autonomous municipalities under the direct control of central government (Beijing, Tianjin, Shanghai et Chongqing), and five autonomous regions (Guangxi, Inner Mongolia, Ningxia, Xinjiang and Tibet). In our econometric analysis, the autonomous region of Tibet is not included for lack of data, the statistics of Chongqing, created in 1997, have been included in those of Sichuan, this leads to retain 29 provinces.

from *Comprehensive statistical data and materials on 50 years of New China* for 1952-1998, and completed by *China statistical yearbook*.[12].

To calculate the capital stock, we need the initial capital stock for the estimation period, i.e. 1992. We estimate it using inventory permanent method and supposing an annual depreciation rate of 5 %, such as: $KR_t=(1-0.05)KR_{t-1}+IR_t$ where KR and IR represent capital stock and investment in constant prices. This formulation compels to know GFCF during the preceding twenty years and amounts to consider that in 1972 capital stock is equal to investment. The capital stock in 1992 (KR_{92}) is equal to the sum of all past twenty years' investments in constant prices, net of depreciations. The calculation formula is such as:

$$KR_{92}=\sum_{n=0}^{19} IR_{72+n}*0.95^{20-n}+IR_{92} \text{ where } KR_{72}=IR_{72}$$

Once estimated the initial capital stock in 1992 and as the capital depreciation data for each province are available from 1993, the capital stock estimation for the period from 1993 to 2001 is calculated such as: $KR_t=KR_{t-1}+IR_t-DR_t$, where DR represents real depreciations which are nominal depreciations deflated by price indices of investment in fixed assets.

On average, the total factor productivity of the Chinese provinces increased at an annual average rate of 2.2 % from 1993 to 2001. It has improved during the whole estimated period, but with a decreasing trend (figure 2). The most important growth rate of the productivity is observed in 1993 when it attained 5 %. The productivity growth rate decreased until 1 % in 1998, and then stayed at this level until 2001. The productivity improvement is due to the technical progress, which has met an annual average growth rate of 2.5 % from 1993 to 2001. Inversely, the technical efficiency has deteriorated at a rate of 0.3 % per year on average during the same period.

Total factors productivity does not increase at the same pace in the Chinese provinces. In eastern, central and western regions[13], the growth rate is respectively of 3 %, 2 % and 1 %

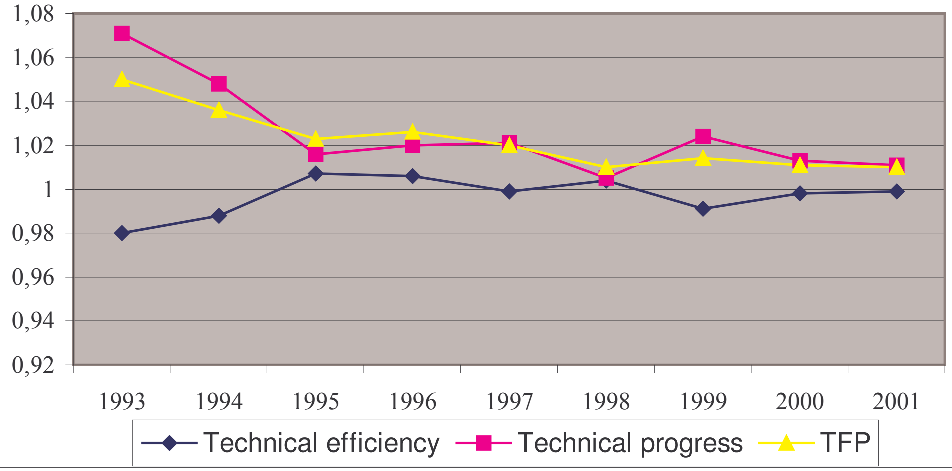
[12] Gross fixed capital formation in constant prices is calculated as GFCF in current prices divided respectively by its prices for the period from 1972 to 1991 and prices of investment in fixed assets from 1992 to 2001, which correspond in China two different series. GFCF prices are obtained from Zhongguo Guorei ShengShang Zongzhi Hesuan Lishi Ziliao, 1952-1995. The lacking data for several provinces are replaced by detail prices (see Lin and Liu, 2002). The price indices of investment in fixed assets are originated from *China Statistical Yearbook*. It should be better to use the same deflator for the whole calculation period, but GFCF prices are available only until 1995, and the price indices of investments in fixed assets are available only since 1992. We have used the same deflator (prices of fixed investments) for the whole estimation period (1993-2001).

[13] Eastern region includes Beijing, Tianjin, Hebei, Liaoning, Shanghai, Jiangsu, Zhejiang, Fujian, Shandong, Guangdong and Hainan. Central region includes Shanxi, Inner Mongolia, Jilin, Heilongjiang, Anhui, Jiangxi, Henan, Hunan, Hubei and Guangxi; Weastern region concerns Sichuan (including Chongqi), Guizhou, Yunnan, Shannxi, Gansu, Qinghai, Ningxia and Xinjiang.

per year on average from 1993 to 2001 (see table A1 in annex). But in central and western regions the annual growth rate becomes null since 1998. Eastern region has the fastest average annual growth rate of technical progress (4 %), i.e. the double of central and Western regions' one. Concerning the technical efficiency, Eastern region is not better than Center region. The annual average growth rate of the technical efficiency is null in Eastern as in Center, while Western region has deteriorated at the pace of 1 % per year on average during the studied period.

During the estimation period from 1993 to 2001, the annual average growth rate of the total factors productivity is between -1.8 % for Guangxi and 8.1 % for Shanghai, that of the technical progress between 0 % for Gansu and 1.8 % for Shanghai, and that of the technical efficiency between -2.5 % for Shanxi and 2.8 % for Anhui (see table A2 in annex).

Figure 2. Malmquist indices relative to total factor productivity and its two components (geometric average of the Chinese provinces)



Note: A value greater than one indicates productivity improvement; and inversely a value less than one means productivity deterioration.

4. Econometric model of the productivity effects of different education levels

As explained in section 2, the waited effects of the three (primary, secondary and university) education levels on technical efficiency and progress may be different, three functions relative to technical efficiency change ($\dot{TE}$), technical progress ($\dot{TP}$), and total factor productivity growth ($\dot{TFP}$) will be successively estimated. We recall that primary-education level (EDUP), secondary-education level (EDUS) and university-education level

(EDUU), are measured as the ratios of the total number of graduates only from primary schools, only from secondary schools and only from universities relative to total population. They are relative to the case without education.

Among the explanatory variables, next to the three education level variables, openness is often considered as one of major factors explaining productivity growth. Trade openness, measured by exports relative to GDP (X), exerts a favourable effect on productivity through a shift of production factors into the export sector which is generally considered as more efficient than the other sectors (Feder,1983). As this sector is dominated by light industry of consumer goods (55% of exports in 2001[14]) which is very labour intensive and corresponds to the comparative advantage of China (Yue and Hua, 2002), its technical efficiency is probably higher in this sector than in heavy industry or in agriculture as well as in the service sector. The export sector provides furthermore external economies to the whole economy through the improvement of management skill and labour training.

On the other hand, the impact of the export sector on the technical progress is uncertain. The industry of consumer goods or of small equipments, on which the export expansion is based in China, is less capable to generate technical progress than the heavy industry, all the more since a great part of this industry is only assembling of imported components. Consequently, it is possible that an increasing ratio of exports to GDP would be associated with a slow down in the technical progress.

The favourable effect of openness also passes through foreign direct investments (FDI) (Dayal-Gulati and Husain, 2002), measured as the ratio of FDI over gross fixed capital formation. In China, as in other developing countries, foreign investments are concentrated in the sector of tradable goods, chiefly in industry. One supposes that foreign firms bring in technological improvements and their know-how[15]. This positive action occurs through the creation of foreign companies more productive than domestic firms and through the diffusion of technical innovations and better management in these firms. This imitation effect occurs in competing domestic firms, but still more in firms which are suppliers or buyers of foreign enterprises (Sun, 1998).

We introduce also a ratio of capital-labour (KL) which supports technical progress but simultaneously induces a lesser efficiency due to the drawbacks in the management of more capitalistic and sophisticated technologies. Real effective exchange rate (ER) is also

[14] *China Statistical yearbook*
[15] About the numerous studies of these effects, see Chen and Démurger (2002)

introduced to capture the direct effects on productivity, which do not pass through openness and capital intensity as in Harris (2001) and Guillaumont Jeanneney and Hua (2003).

Next to these variables related to the effects of openness and exchange rate polices, we introduced real GDP per capita lagged one period (YRP_{-1}) to test an eventual convergence effect, following the traditional growth theory. In order to control for the transitory effect of business cycle on the utilization rate of production factors, we introduced the gap of the ratio between changes in inventories and GDP to its trend (INV) in the equation of technical efficiency and thus in the equation of total factor productivity growth. In fact, this ratio has met a decreasing trend during the estimated period which probably reflects a better efficiency in input utilization and in the management of finished goods, as this is normal in a transition economy. So we consider that a positive gap relative to trend reflects a flat overall economic situation and inversely. This gap is thus defined as business cycle indicator.

Finally, we introduce the importance of public enterprises (ENP) as transmission channel from which education influences efficiency change through the redistribution of educated people towards the non-state sector. Indeed we may suppose, as the essential of bank funding is affected to public enterprises in China, they make huge investments (with a high content of technological innovations) more easily than other enterprises, but in return their technical efficiency is constrained by an excess of less-educated workers difficult to be made redundant and by the moving out of the higher-educated workers who prefer to work in more efficient non-state sector because of higher salaries (Yue, 2003). This reallocation of university-educated workers into the more efficient sector favors efficiency improvement, and thus productivity growth.

Three functions can be therefore written as follows:

For technical efficiency growth (equation 1):

$$\dot{TE}_{it}=a_0+a_1EDUP_{it}+a_2EDUS_{it}+a_3EDUU_{it}+a_4X_{it}+a_5FDI_{it}+a_6KL_{it}+a_7ER_{it}+a_8YRP_{it-1}+a_9INV_{it}+a_{10}ENP_{it}$$

The expected signs are such as:

$a_1<0$, $a_2<0$, $a_3>0$, $a_4>0$, $a_5>0$, $a_6<0$, $a_7>0$, $a_8>$ or <0, $a_9<0$, $a_{10}<0$

For technical progress (equation 2):

$$\dot{TP}_{it}=b_0+b_1EDUP_{it}+b_2EDUS_{it}+b_3EDUU_{it}+b_4X_{it}+b_5FDI_{it}+b_6KL_{it}+b_7ER_{it}+b_8YRP_{it-1}+b_9ENP_{it}$$

The expected signs are such as:

$b_1<0$, $b_2<0$, $b_3>0$, $b_4>$or<0, $b_5>0$, $b_6>0$, $b_7<0$, $b_8>$ or<0, $b_9>0$

For total factor productivity growth (equation 3):

$$\dot{TFP}_{it} = c_0 + c_1 EDUP_{it} + c_2 EDUS_{it} + c_3 EDUU_{it} + c_4 X_{it} + c_5 FDI_{it} + c_6 KL_{it} + c_7 ER_{it} + c_8 YRP_{it-1} + c_9 INV_{it} + c_{10} ENP_{it}$$

The expected signs are such as:

$c_1<0$, $c_2< 0$, $c_3>0$, c_4<or>0, $c_5>0$, c_6>or <0, c_7<or>0, c_8<or>0, $c_9<0$, c_{10}<or>0

In order to show if the effects of different education levels on efficiency offset each other, we introduce the ratio of the total number of graduates from primary schools, secondary schools and universities over total population into equations instead of the three education levels.

Finally, in order to measure the total effect of the three education levels on efficiency change, technical change and total factor productivity change, we regress public employment ratio representing transmission channel on three education levels, and replace the ratio by estimated residual in the three previous functions (equations 1, 2 and 3). In fact, the residual represents the part of public employment, which is not explained by the reallocation of educated people. The only consequence of this substitution of the residual to the public employment ratio is the modification of the coefficients associated with the three education levels that from now on captures the total effects of education on efficiency change and on total factor productivity growth.

5. Estimation and econometric results

5.1. Data and sources

Econometric estimations of the impact of different education levels on productivity change and on its two components are based on provincial annual data for the period from 1993 to 2001. They are panel estimations and all variables are expressed in logarithms. The data concerning the Chinese provinces are issued from *China Statistical Yearbook*, apart from contrary indication. Several arguments justify the choice of the estimation period. Firstly, it is since 1992-1993 that the transition of China towards a market economy is accelerated (Guillaumont Jeanneney and Hua 2004). Secondly, this period choice allows using relative homogenous data, particularly concerning exports and price indices of investments in fixed assets (see note 7 in section 3.2).

Malmquist indices relative to TFP change and to its two components, defined in previous section, are calculated by DEAP software (Coelli, 1996). As their values are around one, we multiplied them by 100 and then expressed in logarithms to obtain an approximation of productivity change.

As cited in the introduction, the problems of education measures may explain why the positive effects of education in theoretical growth models are often not confirmed by empirical estimation. Different kinds of measures for proxy of education lead to different results. In fact, the enrolment rates, education spending and related inputs are often used to measure human capital; however, these variables cannot measure correctly the human capital stock. In this study, we use the ratio of the total number of graduates from schools over total population as the education stock measures of the Chinese provinces. More precisely, primary education is calculated as the ratio of the total number of graduates only from primary schools over a province's total population. In the same way, secondary education is calculated as the ratio of the total number of graduates only from secondary schools over a province's total population. University education is calculated as the ratio of the total number of graduates from universities over a province's total population.

The education data for 1990 and 2000 are respectively obtained from 4^{th} and 5^{th} Population Census of China, edited by the National Population Census Office and published by *China Statistical Yearbook*, 2001. The data for 1996, 1997, 1998, 1999 and 2002 are obtained from the annual sample survey published in different editions of *China Statistical Yearbook*. For 1993, 1994, 1995 and 2001, we use perpetual inventory method as in Démurger (1999) and Wang and Yao (2003). This method consists to calculate the number of diploma holders (DIP) by adding to accumulated diploma holders available in previous year newly holders of diploma (NDIP) and by removing the number of death of corresponding year and then to divide total number of diploma holders by population. The formula of the calculation is as fellows:

$$EDU_{t+1}=\frac{DIP_{t+1}}{POP_{t+1}}=\frac{DIP_t+NDIP_{t+1}-\delta*DIP_t}{POP_{t+1}}$$

where α represents death rate.

The trade openness is calculated as export ratio of each province to its GDP. Foreign direct investments ratio (FDI) is direct investments relative to gross fixed capital formation. Capital intensity is the ratio of capital in constant prices to total employment. The real effective exchange rate indices are calculated as the nominal effective exchange rate indices (base 1995 =100) multiplied by the ratio between the consumer price index of each province and the average of consumer price indices of its fifteen most important trading partners. An increase of real effective exchange rate corresponds to an appreciation of the Renminbi. The

GDP per capita of each province is calculated from GDP expressed in 1995 constant yuans and divided by population. The business cycle indicator is represented by change in inventories/GDP purged from its trend. The employment rate of public enterprises is measured by the number of workers in public enterprises relative to total employment of each province.

5.2. Econometric tests

Before the econometric estimation, we did several tests for the pertinence of estimation. The stationnarity test of Im-Pesaran-Shin allows us to reject unit root hypothesis for all variables in our estimation (table 2). The results of Breusch and Pagan LM test and Hausman specific test indicate that we cannot reject the hypothesis of one model with fixed effect (table 3).

Main potential econometric problem concerns the endogeneity of macroeconomic control variables. Real effective exchange rate is used here as an independent variable to explain productivity growth. However, we have supposed an inverse relation in Guillaumont Jeanneney and Hua (2002) in which by applying Balassa-Samuelson effect, the real effective exchange rate of the provinces is explained by the ratio of GDP of each province to that of its foreign trading partners[16] on the one hand and to GDP of China as a whole on the other hand. These variables are used here as instruments of the real effective exchange rate. For export rate, ratio of foreign direct investments, capital intensity and ratio of changes in inventories, instruments are constituted by variables lagged one year and by dummy variable equal to one for coastal provinces. The results of Arellano-Bond test for AR(2) reject the existence of autocorrelation for these instrument variables. The results of DWH test do not allow us to reject endogeneities of these variables (see table 3). The results of Pagan/hall heteroskedasticiy test, which is the most pertinent in estimation with instrumental variables, allow us to prefer to Generalized Moments Model with instrumental variables (Baum, Schaffer and Stillman, 2003). Finally, the pertinence and the validity of instruments are tested using Sargan over-identification test. The results do not allow us to reject the hypothesis that the instruments are independent of error terms.

Table 2. Stationnarity test of Im-Pesaran-Shin[a]

Technical efficiency change	-5.999***
Technical progress	-3.74***

[16] Source IMF *International Financial Statistics*

Total factor productivity change	-18.167***
Primary education	-5.504***
Secondary education	-3.319***
University education	-7.823***
Export ratio	-7.273***
FDI/FBCF	-3.625***
Capital intensity	-4.975***
Real effective exchange rate	-5.667***
Real GDP per capita lagged one year	-2.24**
Gap to trend of changes in inventories /GDP	-3.74***
Ratio of public employment	-2.164**

a. Panel t-statistics

5.3. Econometric results

The econometric results are reported in tables 3 to 5. Table 3 presents the regression results of basic model that includes the ratio of public employment corresponding to the transmission channel of the education levels to productivity. Thus the coefficients relative to these education levels represent their *direct* impacts on productivity growth, which do not pass through public sector. Table 4 presents the regressions of public employment on three education levels. The results show that actually public employment is one transmission channel of education to productivity growth, in particular through primary education and university education. Effectively, the university-educated people tend to move out the public sector, while the primary-educated people tend to stay in the sector. This movement is not significant for the secondary-educated people. The residual of this regression is substituted to the ratio of public employment for the productivity growth estimations presented in table 5. The results of these estimations with residuals show the *total (direct and indirect)* impact of education levels on technical efficiency change and thus productivity growth.

From the results reported in these tables, most coefficients are significant with waited signs. We can see from tables 3 and 5 that export ratio exercises a positive effect on efficiency improvement, but negative on technical progress. Foreign direct investments favor technical progress as well as capital intensity does, while capital intensity is a factor of less efficiency. A real appreciation of the Renminbi exerts a positive effect on efficiency change, but a negative one on technical change. These two opposite effects set off each other and lead a statistically non-significant effect on productivity growth. Finally, the diminution of total demand related to business cycle (measured by changes in inventories) lessens technical efficiency by reducing utilization ratio of production capacities.

Table 3 allows to measure *residual or direct* impact of education levels on productivity, which means the impacts that does not pass through the ratio of public employment; while table 5 allows estimating total effects. We observe that, according to table 3, primary education and secondary education exert direct negative impacts on technical efficiency change. On the contrary, university education is not statistically significant. Despite the three education levels exert positive effects on technological progress, only university education is statistically significant. As waited, university educated people favors more easily the development and assimilation of new products. This leads that the direct impact of university education on total factors productivity is positive. The effects of primary education and secondary education on productivity are not statistically significant.

Total impact of education levels on productivity change depends evidently on the impact of education levels on the ratio of public employment identified as channel of transmission. The table 4 indicates that university education as waited exerts a negative effect on ratio of public employment because university-educated people prefer to work in the non-state sector, while primary education exerts a positive effect. In fact, the primary-educated people are more constraint to stay in the public sector (Yue, 2003).

By comparing tables 3 and 5, we observe that if the direct or residual impacts of primary education are statistically significant for efficiency change at the 5% level, their total impacts are now significantly positive at the 1% level. The coefficient of primary education passes from –0.05 to –0.07. We observe also that university education becomes now statistically significant at the 10% level. The university-educated people who move out the public sector exert a positive effect on efficiency improvement. It results that total impact of university education on total factors productivity is significantly positive (0.03). In other words, university education in the nineties has contributed to improve technical efficiency and technical progress, and finally to increase total factors productivity.

Finally, the positive effect of university education on efficiency change offsets the negative ones of primary and secondary education. This leads an insignificant direct effect of education once the three education levels are considered together (equation 2, tables 3). The total effect of education is statistically significant. This offset does not exist for technical progress. Thus, education plays a positive effect on technical progress.

5. Conclusion

This paper shows that it is very important to distinguish education levels to study their different (positive or negative) effects on productivity, in particular on efficiency. This may explain why empirical papers do not confirm the positive role of education in theoretical growth models.

The econometric results show that university education exerts a positive impact on efficiency change, technical change and productivity growth, while primary education and second education exert a negative impact on efficiency change. Moreover, the positive effect of university-educated people on efficiency improvement is through their mobility towards more efficient non-state sector.

At the same time, we observe a striking fact that according to the DEA Malmquist index the efficiency has fallen in China from 1993 to 2001 at a rate of 0.3% a year. So the true stake to to keep the sustained long-term growth is the efficiency improvement. These results justify completely the development of education, particular university education, which is actually one priority objective of the Chinese government.

Table 3. Estimation of productivity growth and its components: basic model

	Technical efficiency change		Technical progress		Total factor productivity	
	1	2	3	4	5	6
Primary education	-0.05** (-1.90)		0.03 (1.51)		-0.01 (-0.04)	
Secondary education	-0.06* (-1.84)		0.02 (0.92)		-0.05 (-1.60)	
University education	0.01 (1.19)		0.01** (1.95)		0.03** (2.43)	
Primary, secondary and university education		-0.08 (-1.48)		0.07* (1.99)		0.01 (0.32)
Export ratio	0.04** (2.12)	0.05** (2.36)	-0.03*** (-2.61)	-0.03*** (-2.66)	0.01 (0.73)	0.01 (0.73)
FDI/FBCF	0.02 (0.76)	0.02 (0.89)	0.02** (2.52)	0.02** (2.01)	0.03* (1.73)	0.03* (1.72)
Capital intensity	-0.06*** (-2.95)	-0.05** (-2.33)	0.04*** (3.21)	0.03*** (3.00)	0.01 (0.55)	0.01 (0.78)
Real effective exchange rate	0.18*** (4.13)	0.20*** (4.40)	-0.18*** (-8.54)	-0.18*** (-8.75)	-0.06 (-1.42)	-0.06 (1.13)
Real GDP per capita lagged one period	0.11 (1.47)	0.15* (1.67)	-0.06 (-0.78)	-0.07 (-0.84)	0.09 (0.81)	0.14 (1.19)
Gap to trend of changes in inventories/GDP	-0.02 (-1.54)	-0.03** (-1.98)			-0.01 (-0.68)	-0.01 (-0.81)
Ratio of public employment	-0.03*** (-3.31)	-0.04*** (-3.83)	0.01*** (2.55)	0.01* (1.72)	-0.02* (-1.68)	-0.02** (-1.94)
Number of observations	228	228	228	228	228	228
Adjusted R^2	0.17	0.20	0.59	0.61	0.49	0.47
Breusch and Pagan LM test	28.96	37.34	25.27	27.16	57.08	80.37
Hausman specific test	30.67	20.04	41.89	35.64	38.59	17.11
AR(2) Arellano-Bond Test[b]	0.20	0.13	0.02	0.01	0.06	0.06
Pagan / Hall heteroskedasticity test[b]	0.09	0.09	0.13	0.09	0.08	0.05
DWH test of endogeneity [b]	0.02	0.01	0.000	0.000	0.000	0.000
Sargan over-identification test [b]	0.67	0.67	0.44	0.483	0.58	0.53

Table 4: Estimation of transmission channel of education to productivity

	Ratio of public employment	Ratio of public employment
Primary education	0.55*** (2.88)	
Secondary education	0.02 (0.10)	
University education	-0.45*** (-6.56)	
Primary, secondary and university education		-1.65*** (-7.70)
Number of observation	261	261
Adjusted R^2	0.37	0.20

Table 5. Estimation of total (direct and indirect) impact of education on efficiency change and productivity growth

	Technical efficiency change		Total factor productivity	
	1	2	5	6
Primary education	-0.07*** (-2.71)		-0.001 (-0.04)	
Secondary education	-0.06* (-1.87)		-0.05 (-1.60)	
University education	0.03** (2.24)		0.03** (2.43)	
Primary, secondary and university education		-0.11*** (-2.21)		-0.01 (-1.49)
Export ratio	0.04** (2.12)	0.05** (2.36)	0.01 (0.73)	0.01 (0.73)
FDI/FBCF	0.02 (0.76)	0.02 (0.89)	0.03* (1.73)	0.03* (1.72)
Capital intensity	-0.06*** (-2.95)	-0.05** (-2.33)	0.01 (0.55)	0.01 (0.78)
Real effective exchange rate	0.18*** (4.13)	0.20*** (4.40)	-0.06 (-1.42)	-0.06 (1.13)
Real GDP per capita lagged one period	0.11 (1.47)	0.15* (1.67)	0.09 (0.81)	0.14 (1.19)
Gap to trend of changes in inventories/GDP	-0.02 (-1.54)	-0.03** (-1.98)	-0.01 (-0.68)	-0.01 (-0.81)
Ratio of public employment	-0.03*** (-3.31)	-0.04*** (-3.83)	-0.02* (-1.68)	-0.02** (-1.94)
Number of observations	228	228	228	228
Adjusted R^2	0.17	0.20	0.49	0.47
Breusch and Pagan LM test	28.96	37.34	57.08	80.37
Hausman specific test	30.67	20.04	38.59	17.11
AR(2) Arellano-Bond Test[b]	0.20	0.11	0.06	0.06
Pagan / Hall heteroskedasticity test[b]	0.09	0.09	0.08	0.05
DWH test of endogeneity [b]	0.02	0.01	0.000	0.000
Sargan over-identification test [b]	0.67	0.67	0.58	0.53

b. P value.

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Table A1. Evolution of total factor productivity and its two components in three Chinese regions

	Eastern			Center			Western		
	Technical Efficiency	Technical progress	Total Productivity	Technical Efficiency	Technical progress	Total Productivity	Technical Efficiency	Technical progress	Total Productivity
1993	0,99	1,07	1,06	0,98	1,07	1,04	0,97	1,07	1,04
1994	0,98	1,06	1,04	1,00	1,04	1,04	0,98	1,05	1,03
1995	1,00	1,03	1,03	1,02	1,00	1,02	1,01	1,01	1,02
1996	0,99	1,03	1,02	1,02	1,02	1,04	1,01	1,02	1,03
1997	0,99	1,03	1,03	1,01	1,01	1,02	1,00	1,01	1,01
1998	1,00	1,02	1,02	1,01	0,99	1,00	1,01	1,00	1,00
1999	1,00	1,05	1,04	0,99	1,01	1,00	0,98	1,01	0,99
2000	1,00	1,03	1,02	1,00	1,00	1,00	0,99	1,01	1,00
2001	1,00	1,02	1,02	1,00	1,01	1,01	0,99	1,01	1,00
Average	1,00	1,04	1,03	1,00	1,02	1,02	0,99	1,02	1,01

Table A2. Geometric average of total factor productivity of Chinese provinces and its two component from 1993 to 2001

	Technical efficiency	Technical progress	Total factor productivity
BEIJING	0,986	1,032	1,017
TIANJIN	1,009	1,039	1,048
HEBEI	0,983	1,015	0,998
SHANXI	0,975	1,014	0,988
INNER MONGOLIA	0,991	1,014	1,005
LIAONING	1,009	1,049	1,059
JILIN	1,012	1,017	1,029
HEILONGJIANG	1,002	1,037	1,038
SHANGHAI	1	1,081	1,081
JIANGSU	1,004	1,042	1,046
ZHEJIANG	0,984	1,038	1,022
ANHUI	1,028	1,015	1,044
FUJIAN	1,005	1,024	1,03
JIANGXI	1,001	1,004	1,005
SHANDONG	1,01	1,017	1,027
HENAN	1,002	1,015	1,017
HUBEI	0,998	1,015	1,014
HUNAN	1,013	1,015	1,028
GUANGDONG	1	1,041	1,041
GUANGXI	0,975	1,007	0,982
SICHUAN	0,995	1,016	1,011
GUIZHOU	0,99	1,011	1,001
YUNNAN	0,984	1,015	0,998
SHAANXI	1,002	1,015	1,017
GANSU	1,017	1	1,017
QINGHAI	0,988	1,018	1,006
NINGXIA	0,997	1,034	1,03
XINJIANG	0,976	1,046	1,021
HAINAN	0,979	1,049	1,027
Average	**0,997**	**1,025**	**1,022**